Development of Negative Tone Chemically Amplified Molecular Resist for Extreme Ultraviolet Lithography towards 11nm half-pitch Resolution

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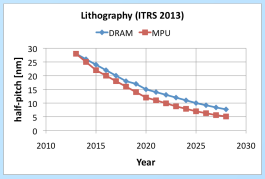
Introduction

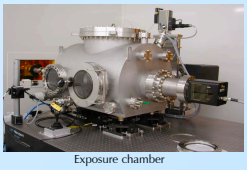
According to the International Technology Roadmap of Semiconductors (ITRS) EUV lithography is one of the leading candidates to replace current manufacturing processes. The move to a much shorter wavelength for patterning has made the development of new photo resist platforms necessary. To date no suitable resist has emerged that meets all the requirements as laid out in the ITRS for 2017, when EUVL is scheduled to be introduced into high volume manufacture.



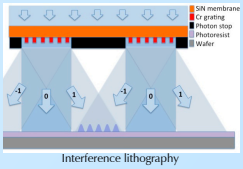
In addition to the target for 2017, new material platforms should also have the potential to meet the outlined specifications beyond 2017 to ensure a useful lifespan for next generation lithography. We are developing a molecular resist platform for EUV application.

EUV Exposures

Samples were primarily exposed at the interference lithography tool (XIL beamline) pf the Swiss Light Source at the Paul Scherrer Institute in Villigen, Switzerland.



Exposure chamber



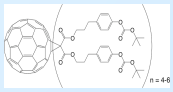
Interference lithography

The tool currently holds the resolution record in optical lithography being able to pattern 7 nm lines in HSQ.

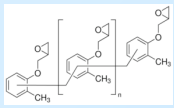
Resist Material

Resist is a blended formulation of up to 5 components:

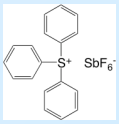
- Molecular resin



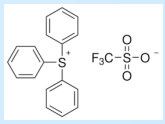
- Crosslinker



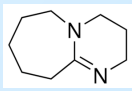
- Photo acid generator



- Quencher

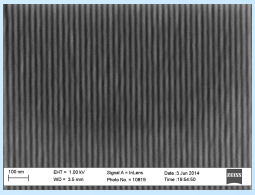


- Nucleophilic base

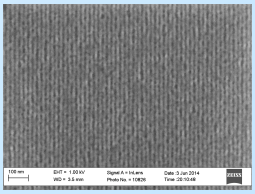


Resist Performance I

Exposure of material IM-MFPT-47 at high resolution showing 13 nm and 11 nm half-pitch patterning.



CD: 13.3 nm
Dose: 48 mJ/cm2*
LER: 3.77 nm

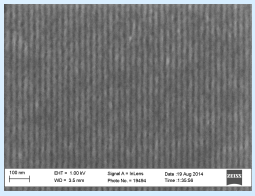


CD: N/A (11 nm)
Dose: 66 mJ/cm2*
LER: N/A

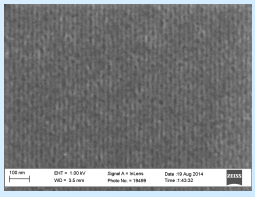
*dose estimate

Resist Performance II

Optimization of synthesis and formulation lead to a new resist variant IM-xMT-C2A with improved sensitivity while maintaining high resolution capability.



CD: 13.8 nm
Dose: 25 mJ/cm2*
LER: 6.6 nm

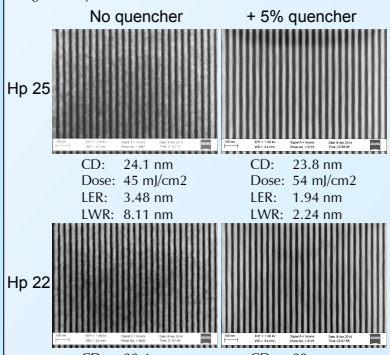


CD: N/A (11 nm)
Dose: 44 mJ/cm2*
LER: N/A

*dose estimate

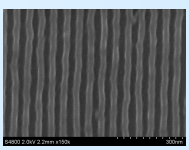
Quencher

Addition of quencher improves the LER of the material significantly as is demonstrated below.

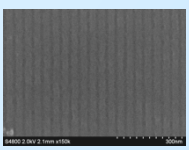


MET Exposures

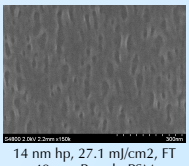
Material was also exposed at the Berkeley Micro Exposure Tool (MET). This system uses a reflective mask and an optical reduction system impacting the aerial image quality.



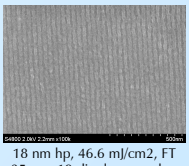
30 nm hp, 25.7 mJ/cm2, FT
40 nm, 18-dipole



22 nm hp, 23.7 mJ/cm2, FT
25 nm, 18-dipole



14 nm hp, 27.1 mJ/cm2, FT
40 nm, Pseudo-PSM



18 nm hp, 46.6 mJ/cm2, FT
35 nm, 18-dipole, quencher

Etch Durability

The etch resistance of the resist material was measured by transferring arrays of 10 μm stripes into silicon. After each step the thickness is measured via surface profiler allowing the calculation of the etch rate. For comparison SAL601 is etch alongside as a control.

Conditions	
SF_6 flow rate (sccm)	25
C_4F_8 flow rate (sccm)	30
RF power (W)	20
ICP power (W)	220
Pressure (mT)	15
Temp (°C)	5
Backside He (T)	10

Conditions	
SF_6 flow rate (sccm)	15
CHF_3 flow rate (sccm)	50
RF power (W)	20
ICP power (W)	200
Pressure (mT)	15
Temp (°C)	5
Backside He (T)	10

Summary

We have presented assessment of a molecular resist platform with high resolution capability beyond the target of the ITRS for 2016. The materials were able to fully resolve at 13 nm half-pitch as well as promising initial results at the 11 nm node. The role of quencher in the formulation was highlighted and the etch durability of the material investigated.

It also shows good initial results at the MET, a tool using an optical system similar to the equipment that will be used for high volume manufacturing in the future. It is seen that the formulation needs to be adapted to the imaging conditions of the MET to transfer its excellent pattern capability to this exposure method.

Acknowledgements

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